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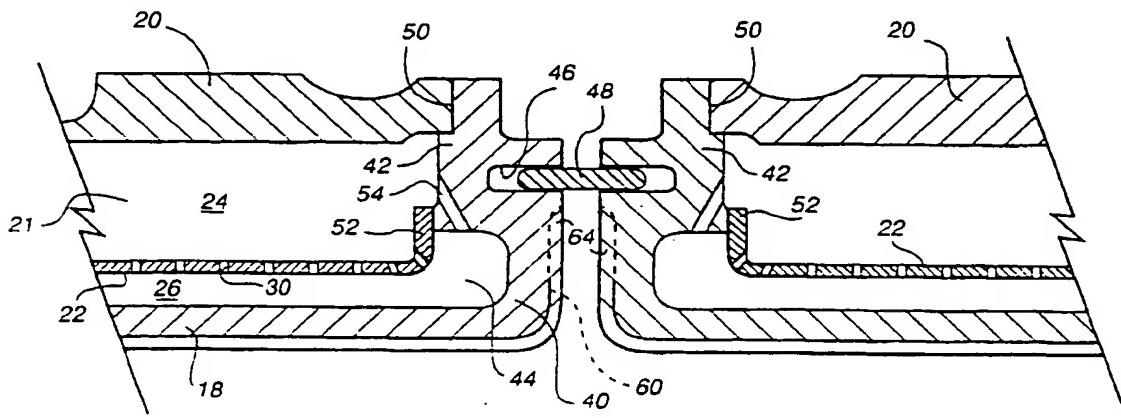
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(54) A method of controlling the side wall thickness of a turbine nozzle segment for improved cooling

(57) A gas turbine nozzle segment (10) has outer and inner bands (12, 14) and a vane (16) extending therebetween. Each band has a side wall (40), a cover (20) and an impingement plate (22) between the cover and nozzle wall defining two cavities (24, 26) on opposite sides of the impingement plate. Cooling steam is supplied to one cavity for flow through apertures (30) of the impingement plate to cool the nozzle wall. The side wall

of the band has an intumed flange (40) defining with the nozzle wall (18) an undercut region (44). The outer surface of the side wall is provided with a step (60) prior to welding the cover to the side wall. A thermal barrier coating (54) is applied in the step and, after the cover is welded to the side wall, the side wall is finally machined to a controlled thickness removing all, some or none of the coating.

Fig. 2



Description

[0001] The present invention relates to impingement cooling of a gas turbine nozzle band side wall in a design where the weld joint between the nozzle segment cover and the nozzle side wall is remote from the nozzle wall exposed to the hot gas path and particularly relates to a method of controlling the side wall thickness of the nozzle band to facilitate cooling thereof.

[0002] In current gas turbine designs, nozzle segments are typically arranged in an annular array about the rotary axis of the turbine. The array of segments forms outer and inner annular bands and a plurality of vanes extend between the bands. The bands and vanes define in part the hot gas path through the gas turbine. Each nozzle segment comprises an outer band portion and an inner band portion and one or more nozzle vanes extending between the outer and inner band portions. In current gas turbine designs, a cooling medium, for example, steam, is supplied to each of the nozzle segments. To accommodate the steam cooling, each band portion includes a nozzle wall in part defining the hot gas path through the turbine, a cover radially spaced from the nozzle wall defining a chamber therewith and an impingement plate disposed in the chamber. The impingement plate defines with the cover a first cavity on one side thereof for receiving cooling steam from a cooling steam inlet. The impingement plate also defines, along an opposite side thereof and with the nozzle wall, a second cavity. The impingement plate has a plurality of apertures for flowing the cooling steam from the first cavity into the second cavity for impingement cooling the nozzle wall. The cooling steam then flows radially inwardly through cavities in the vane(s), certain of which include inserts with apertures for impingement cooling the side walls of the vane. The cooling steam then enters a chamber in the inner band portion and reverses its flow direction for flow radially outwardly through an impingement plate for impingement cooling the nozzle wall of the inner band.

[0003] The spent cooling medium flows back through a cavity in the vane to an exhaust port of the nozzle segment.

[0004] The cover provided each of the outer and inner band portions is preferably welded to the corresponding nozzle side wall. In prior designs, the weld joint between the cover and the nozzle side wall was disposed at a radial location between the nozzle wall and the spline seal between side walls of adjacent nozzle segments. In that location, the weld was exposed to the high temperature gases in the hot gas flow path and was very difficult to cool. Thus, weld joint fatigue life was significantly reduced due to its proximity to the hot gas path. Moreover, the location of the weld was not optimum for manufacturing repeatability and was very sensitive to manufacturing tolerances. The weld joint was characterized by variable wall thicknesses which increased the stress at the joint, decreased low cycle fatigue and lim-

ited the life of the parts. The wall thickness at the weld after machining is also a variable which could not be tolerated in the manufacturing process.

[0005] In a current nozzle segment design, the weld joint between the cover and nozzle side wall is on the side of the spline seal remote from the nozzle wall exposed to the hot gas path. That is, the weld joint between the cover and the nozzle side wall of the outer band is located radially outwardly of the spline seal between adjacent outer bands while the weld joint between the cover and the nozzle side wall of the inner band is located radially inwardly of the spline seal between adjacent inner bands. This reduces the temperature of the weld joints during turbine operation, reduces the stresses across the joints, both thermal and mechanical, eliminates any requirement for machining after welding and results in joints of constant thickness and higher fatigue life. The location also leads to improved machinability and tolerance to weld defects.

[0006] To provide that weld location, undercut regions adjacent the side walls of the nozzle segment bands are formed. Particularly, each undercut region includes a side wall or edge of the nozzle segment and an inturned flange extending inwardly from and generally parallel to the nozzle wall and spaced from the nozzle wall. Cooling the nozzle band side wall or edge, however, is quite difficult in view of the undercut region which spaces the side wall or edge a substantial distance from the impingement plate which, in turn, reduces the effectiveness of impingement cooling the segment side wall.

[0007] With the present invention, improved side wall fabrication and cooling is provided. Particularly, with the weld joint between the cover and the nozzle side wall located remotely from the hot gas path through the turbine, side wall cooling is facilitated by controlling the thickness of the side wall to a very tight tolerance. As will be appreciated from the foregoing, the side walls of each nozzle segment are very difficult to cool due to the large impingement gap in the undercut region, i.e., the substantial distance between the apertures of the impingement plate nearest the side wall and the side wall *per se*. The side wall is also not robust to manufacturing processes. This design is very dependent upon the casting process for the nozzle segment and the weld or other distortions that may occur during processing of the segment.

If the side wall thickness is too thick, this results in reduced low cycle fatigue due to increased thermal strains on the segment. Increased stresses would also be introduced in this area or other areas of the nozzle segment. Side wall thickness variability is also a problem because post-cast machining operations may leave the wall too thick or too thin or perhaps even remove a portion of the wall. If the wall becomes too thick, reworking the segment is typically not allowed and the segment would have a greatly reduced part life. Also, the wall thickness might be so thick that the part could not be used. A thin wall, similarly as a thick wall, would cause stresses to either increase at the side wall location or in

other areas of the segment. As a consequence, it has been determined that side wall thickness must be maintained within very tight tolerances in order to maintain appropriate cooling within the design parameters.

[0008] In accordance with a preferred embodiment of the present invention, the side wall thickness of the nozzle segment is controlled by preferably premachining a step in each of the side walls of the nozzle along the outer surface thereof prior to welding the cover to the nozzle segment. The step in the side wall is based on the inside surface position of the side wall, i.e., the datum for the machining is the internal wall surface. A thermal barrier coating (TBC) is applied in a relatively thick layer in the step by masking past the premachined surfaces. Subsequent to welding the covers to the nozzle segments, the side wall is finally machined, i.e., the thermal barrier coating is machined and serves as a buffer for and an accommodation to manufacturing tolerances to afford a predetermined side wall thickness after final machining. Thus, if the cast side wall of the nozzle segment is out-of-tolerance and after machining the TBC is thick, the TBC affords added protection to the side wall as it reduces the thermal gradient through the metal. If the TBC after final machining is relatively very thin or non-existent along the premachined step, due to out-of-tolerance formation of the side wall, this too is acceptable due to the purge of the cavity, i.e., the impingement cooling, and the fact that the wall is of known thickness. Thus, the manufacturing process provides the thermal barrier coating as a means to absorb or accommodate manufacturing tolerances to provide a very controlled wall thickness which will greatly enhance the low cycle fatigue of the segment and reduce any need to scrap the segment by reason of the part being out of tolerances.

[0009] In a preferred embodiment according to the present invention, there is provided a method of manufacturing nozzle segments having nozzle bands and vanes extending therebetween, the nozzle bands having side walls adjacent one another when the nozzle segments are assembled for use in a gas turbine, comprising the steps of applying a thermal barrier coating to at least one side wall of each nozzle band and machining one side wall with the thermal barrier coating serving as a buffer to accommodate manufacturing tolerances in the segment thereby controlling the side wall thickness of the nozzle segment.

[0010] The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:-

FIGURE 1 is an exploded, perspective and schematic view of a nozzle segment constructed in accordance with the present invention; and

FIGURE 2 is an enlarged fragmentary cross-sectional view illustrating a joint between side walls of adjacent nozzle segments illustrating the location

of the thermal barrier coating along the side walls of adjoining nozzle segments.

[0011] Referring now to Figure 1, there is illustrated a nozzle segment, generally designated 10, forming a part of an annular array of segments disposed about a gas turbine axis. Each nozzle segment includes an outer band 12, an inner band 14 and one or more vanes 16 extending therebetween. When the nozzle segments

are arranged in the annular array, the outer and inner bands 12 and 14 and vanes 16 define in part an annular hot gas path through the gas turbine, as is conventional.

[0012] The outer and inner bands and the vanes are cooled by flowing a cooling medium, e.g., steam, through a chamber of the outer band 12, radially inwardly through cavities in the vanes, through a chamber in the inner band 14 and radially outwardly through the vanes for return of the cooling medium to an exit port along the outer band. More particularly and by way of

example with reference to Figure 1, the outer band 12 includes an outer nozzle wall 18, an outer cover 20 which is disposed over and welded to the outer wall 18 to define a chamber 21 (Figure 2) therebetween and an impingement plate 22 disposed in the chamber 21. The impingement plate 22 defines with the nozzle segment cover 20 a first cavity 24 and, on an opposite side thereof, defines with the nozzle wall 18 a second cavity 26. Cooling medium inlet and outlet ports 25 and 27, respectively, are provided through the cover for supplying the

cooling medium, e.g., steam, to the nozzle vane segment and exhausting the spent cooling steam from the segment. The cooling steam is supplied to the first cavity 24 for passage through a plurality of apertures 30 in the impingement plate 22 for impingement cooling of the

nozzle wall 18. The impingement cooling steam flows from the second cavity 26 into one or more inserts (not shown) in cavities extending through the vane between the outer and inner bands. The vane inserts include a plurality of apertures for impingement cooling of the side walls of the vane. The cooling steam then flows into the chamber of the inner band 14 and particularly into the radial innermost cavity for flow through apertures of an impingement plate in the inner band for impingement cooling the side wall of the inner band. The spent cooling

steam then flows through a cavity in the vane and through the exhaust port of the outer band. For a complete description of an embodiment of the foregoing described cooling circuit, reference is made to U.S. Patent No. 5,634,766, of common assignee, the disclosure of which is incorporated herein by reference.

[0013] Referring now to Figure 2, there is illustrated a juncture between adjacent nozzle segments. It will be appreciated that while the following description is specific with reference to the outer band 12, it is equally applicable to the inner band 14. Thus, each nozzle band (both inner and outer bands) includes a nozzle side wall or edge 40 which extends generally radially between the nozzle wall 18 and the cover 20. The band also includes

an inturned flange 42 spaced from the nozzle wall 18 and defines with wall 18 and side wall or edge 40 an undercut region 44. The inturned flange 42 also includes a circumferentially opening slot 46 for receiving one edge of a spline 48 forming a seal between adjacent nozzle segments.

[0014] As illustrated in Figure 2, the covers 20 are welded to the inturned flanges 42 along opposite edges of the nozzle band. Also, the weld joint 50 lies on the side of the spline seal 48 remote from the nozzle wall 18. By locating the weld joint 50 away from the hot gas path defined in part by nozzle wall 18, the weld joint 50 is subjected to a much lower temperature than if located closer to the hot gas path. Also illustrated in Figure 2 is the impingement plate 22 which has a turned edge 52 along opposite margins for brazing or welding to an inside surface of the inturned flange 42. While apertures 30 are located in each turned edge 52 of the impingement plate, it will be appreciated that there is a substantial distance between the nearest aperture 30 and the side wall or edge 40 in the undercut region 44. This large distance diminishes the effectiveness of the impingement cooling. As set forth in co-pending application Serial No. _____ (Attorney Dkt. 839-742), impingement cooling apertures 54 are formed through the inturned flange 42 to provide cooling steam in the undercut region 44 for direct impingement cooling of side wall 40.

[0015] As noted previously, most preferably the thickness of the side wall 40 is controlled to tight tolerances. The side wall thickness is, however, very sensitive to manufacturing tolerances, i.e., a casting tolerance, as well as weld and machining distortions. By applying a thermal barrier coating as a buffer for the manufacturing tolerance after the covers 20 are welded to the nozzle casting, a known metal wall thickness can be provided upon final machining. To control the thickness of the side wall 40, a step 60 is preferably premachined into the side wall based on the inside position of the wall. That is, the inside surface of the side wall 40 serves as the datum for the machining. The step is preferably provided the side walls after the nozzle covers 20 are welded onto the main nozzle casting of the segment such that distortions caused by the welding are built into the joint. After premachining, the side wall is masked past the premachined surfaces and coated with the thermal barrier coating 64. As illustrated, the coating is also applied to the wall surfaces of the nozzle wall 18 in contact with the hot gases flowing along the hot gas path. The side walls 40 of the nozzle segments are then final-machined, using a method compatible with machining thermal barrier coatings and metal, for example, a creep-feed grind operation. The final machining step can control the wall thickness of the side wall to a very tight tolerance not affected by weld or casting tolerances. The process affords a buffer, i.e., an accommodation that reduces sensitivity to manufacturing tolerances. For example, when the side wall is out-of-tolerance and the thermal barrier coating is thick, the coating is final-ma-

ched to a combined thickness for the side wall plus coating which will meet cooling requirements, i.e., the impingement cooling is sufficient to maintain the side wall within desired temperature ranges while the remaining TBC affords added thermal protection. If the final machining step results in little or no thermal barrier coating along the side wall, the thermal barrier coating is not needed. Impingement cooling of the side wall is effective because the side wall is within the tightly tolerated desired thickness. Thus, the side wall is cooled properly. The capacity to absorb or accommodate manufacturing tolerances using the thermal barrier coating as a buffer enhances the low cycle fatigue of the nozzle segment.

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Claims

1. A method of manufacturing nozzle segments (10) having nozzle bands (12, 14) and vanes (16) extending therebetween, the nozzle bands having side walls (40) adjacent one another when the nozzle segments are assembled for use in a gas turbine, comprising the steps of:
 - applying a thermal barrier coating (64) to at least one side wall of each nozzle band; and
 - machining said one side wall with the thermal barrier coating serving as a buffer to accommodate manufacturing tolerances in the segment thereby controlling the side wall thickness of the nozzle segment.
2. A method according to Claim 1 including forming a step (60) in at least said one side wall of said segment, and applying the thermal barrier coating in said step.
3. A method according to Claim 1 including forming a step in each of the side walls of adjacent nozzle bands, applying a thermal barrier coating in each step, and machining each side wall with the thermal barrier coating serving as a buffer to accommodate manufacturing tolerances in the cast nozzle segments, thereby controlling the side wall thickness of the nozzle segments.
4. A method according to Claim 1, 2 or 3 wherein said step of machining includes removing all of the thermal barrier coating applied to the side wall of the nozzle segment.
5. A method according to Claim 1, 2 or 3 wherein said step of machining includes removing a portion of the thermal barrier coating and leaving a portion of the thermal barrier coating on the side wall.

6. A method according to Claim 5 including leaving a portion of the coating along the entirety of the step formed along the side wall.
7. A method according to any preceding Claim including welding a cover and the nozzle band to one another defining a chamber therebetween for receiving a cooling medium, the step of machining being performed subsequent to welding the cover and nozzle band to one another.

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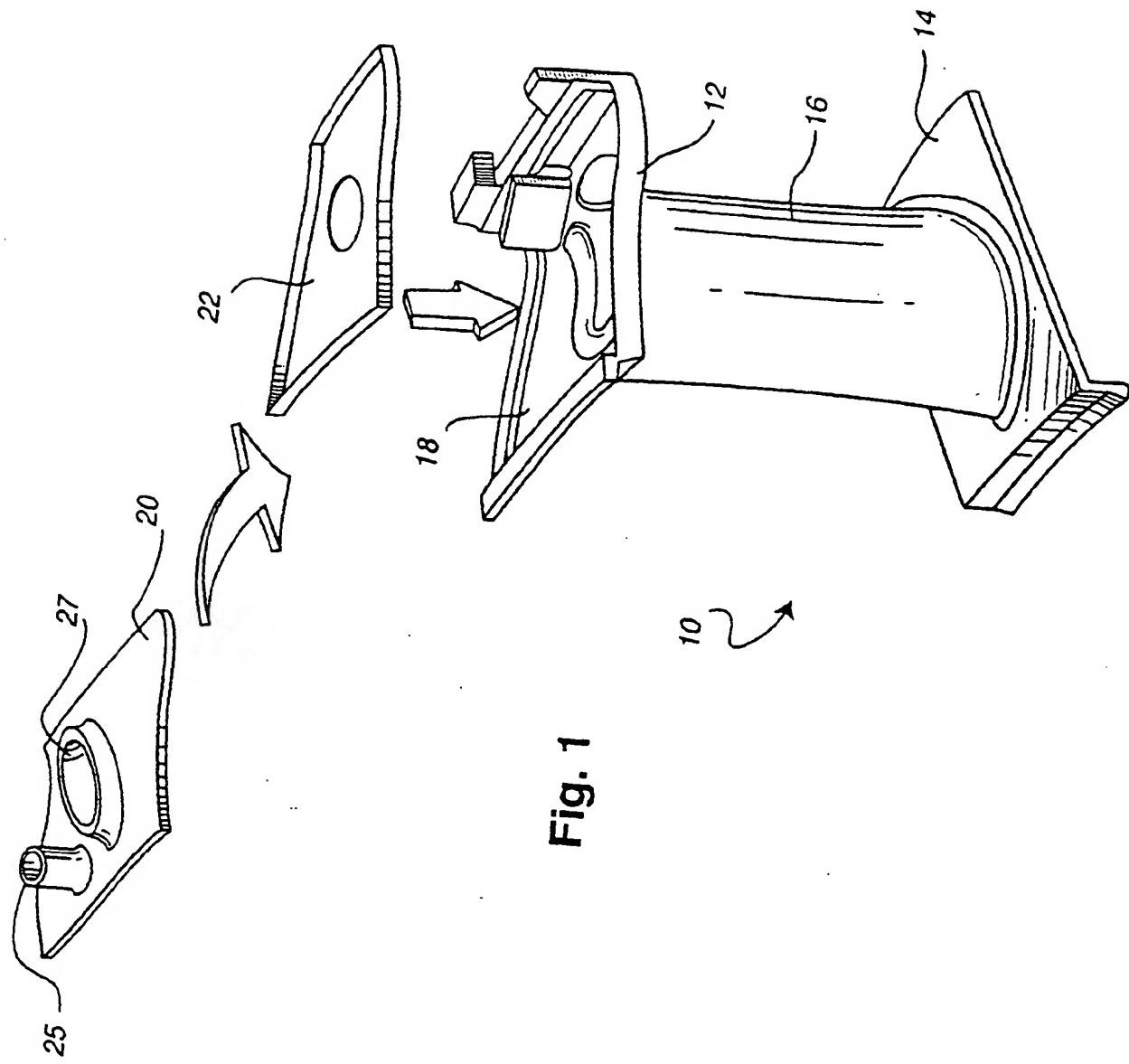


Fig. 1

Fig. 2